Chapter 12 - Sound

Introduction

You have learnt that sound is a form of energy. It is produced by vibrations. Sound waves are longitudinal waves. They are also elastic waves hence they need a material medium for their transmission. They cannot be transmitted in vacuum. They travel in solids, liquids and gases. Their velocity is maximum in solids and least in gases.

We hear various kinds of sound in our daily life, pleasant sounds called the musical sounds, unpleasant sound called the noise, loud sound, high pitched sound etc.

In this chapter let us study the difference between pleasant and unpleasant sound and the factors on which the loudness, pitch etc depend upon.

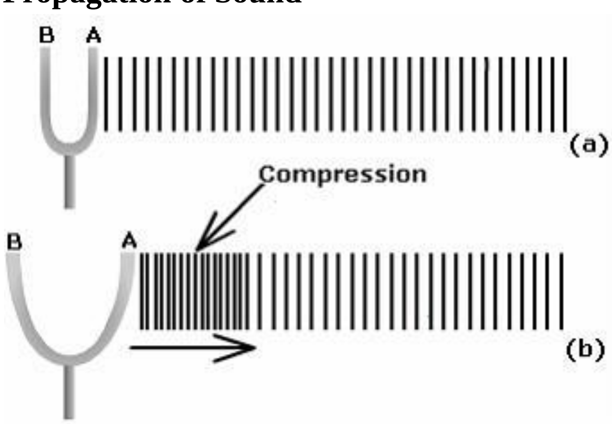
Sound as a Wave

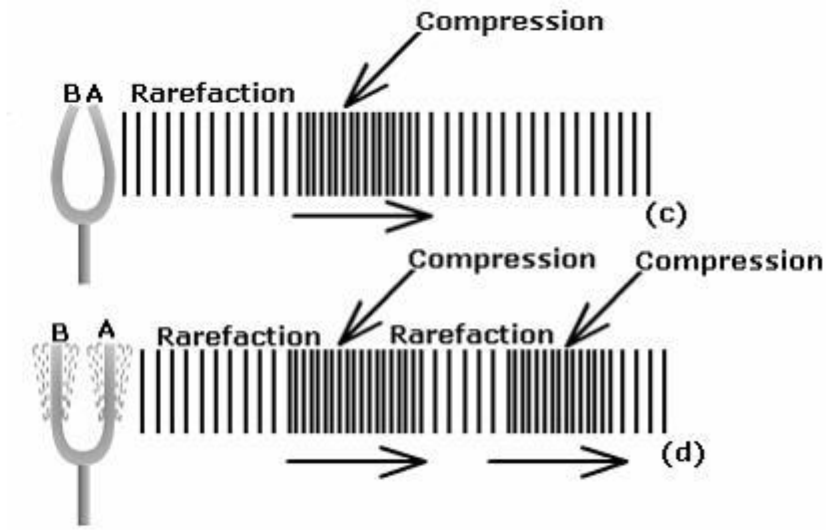
A ringing bell, a thunderclap, laughter, and rock music are sounds that seem very different to us. However, all sounds are alike because they are waves. Let us understand how wave properties can be applied to sound.

Sound is the form of energy propagated as waves which our ears receive. When we speak, our vocal cords vibrate. When we play a guitar, the spring on it makes to and fro motion and produces sound. A tuning fork also produces sound due to its vibrations. So, a body produces sound by virtue of its vibrations. Sound waves cannot travel through vacuum, i.e., they need a material medium to travel.

You can hear because, when sound waves reach your ears, the waves make your eardrums vibrate. Nerves then send to your brain the messages about the vibrations. The brain interprets the messages as sound.

Propagation of Sound





Propagation of sound waves in air from a tuning fork

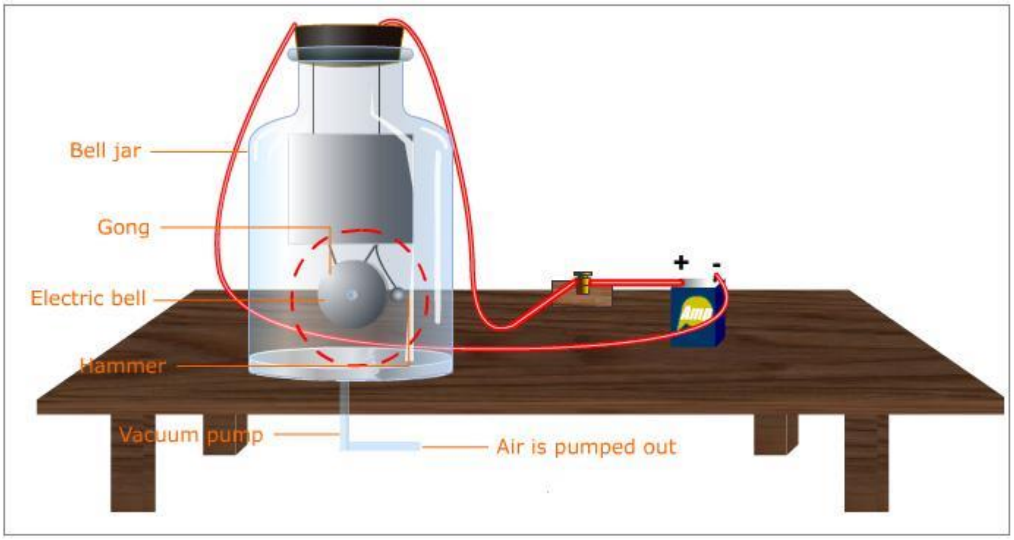
A wave motion, in which the particles of the medium oscillate about their mean positions in the direction of propagation of the wave, is called longitudinal wave.

Sound waves are classified as longitudinal waves. Let us now see how sound waves propagate. Take a tuning fork, vibrate it and concentrate on the motion of one of its prongs, say prong A. The normal position of the tuning fork and the initial condition of air particles is shown in the fig (a). As the prong A moves towards right, it compresses air particles near it, forming a compression as shown in fig (b). Due to vibrating air layers, this compression moves forward as a disturbance. As the prong A moves back to its original position, the pressure on its right decreases, thereby forming a rarefaction. This rarefaction moves forward like compression as a disturbance. As the tuning fork goes on vibrating, waves consisting of alternated compressions and rarefactions spread in air as shown in fig (d). The direction of motion of the sound waves is same as that of air particles; hence they are classified as longitudinal waves. The longitudinal waves travel in the form of compressions and rarefactions.

Sound Needs a Medium to Travel

The origin of sound is always some vibrating body. In some cases the vibrations of the source may be very small or very large that it may not be possible to detect them. This type of vibrations is produced by tuning fork, drum, bell, the string of a guitar etc. Human voice originates from the vibrations of the vocal chords and the sound from the musical instruments is due to the vibrations of the air columns. Sound travels in the form of longitudinal wave and it requires a material medium for its propagation.

Experiment to show that sound waves (mechanical waves) require a material medium for its propagation



Electric bell suspended inside an airtight glass bell jar

An electric bell is suspended inside an airtight glass bell jar connected to a vacuum pump. As the electric bell circuit is completed, the sound is heard. Now if the air is slowly removed from the bell jar by using a vacuum pump, the intensity of sound goes on decreasing and finally no sound is heard when all the air is drawn out. We would be seeing the hammer striking the gong repeatedly. This clearly proves that sound requires a material for its propagation.

Sound can propagate not only through gases but also through solids and liquids. Some materials like air, water, iron etc can easily transmit sound energy from one place to another. On the other hand materials like blanket and thick curtains absorb most of the sound energy.

Basic Terms Connected to Waves

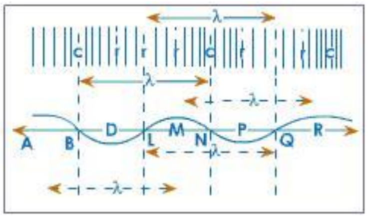
The four important terms used in the study of waves are Wavelength, Amplitude, Frequency and Wave velocity.

Wavelength is the distance between two consecutive points on the wave which are in the same phase. (Same phase means same state of vibrations)

Amplitude is the maximum displacement of the particle from its mean position.

Frequency is the number of periodic oscillations completed in one second. The frequency f = 1/T where 'T' is the time taken to complete one oscillation. The unit of this measure is hertz [Hz].

Wave velocity 'v' is the velocity with which the energy is propagated in a medium.



Sound wave

As wavelength is the distance covered during one oscillation and frequency is the number of oscillations per second, the product of the wavelength and frequency would give us the wave velocity.

Distance travelled in 1 s = number of waves in one second x wave length

Wave velocity = Frequency × Wavelength

or, v = f (x)

Speed of Sound

The flash of lightning due to collision of clouds is seen much before the thunder, although both occur simultaneously. This happens because the velocity of light is greater than the velocity of sound. The speed of sound depends on the properties of the medium through which it travels. The medium can vary in (1) elasticity (2) density (3) pressure and (4) temperature. The speed of sound decreases as it moves from solid to gaseous state. But in any medium the speed of sound increases with increase in temperature. The speed of sound at a particular temperature in various media is listed in the table.

Speed of sound in different media at 25^0C		
State	**Substance**	**Speed in m/s**
Solids	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass(Flint)	3980
Liquid	Water (Sea)	1531
	Water(distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

Reflection of Sound

When sound is incident on a solid or a liquid surfaceit bounces off the surface like light rays. Sound waves also obey the laws of reflection and refraction. For sound waves to reflect, we need extended surface or obstacle of large size. For example, the rolling of thunder is due to successive reflections from clouds and land surfaces.

According to the law of reflection of sound the directions in which the sound is incident and reflected make equal angles with the normal to the reflecting surface and the three lie in the same plane.

Echoes

Like all waves, sound waves can be reflected. Sound waves suffer reflection from the large obstacles. As a result of reflection of sound wave from a large obstacle, the sound is heard which is named as an echo. Ordinarily echo is not heard as the reflected sound gets merged with the original sound. Certain conditions have to be satisfied to hear an echo distinctly (as a separate sound). The sensation of any sound persists in our ear for about 0.1 seconds. This is known as the persistence of hearing. If the echo is heard within this time interval, the original sound and its echo cannot be distinguished. So the most important condition for hearing an echo is that the reflected sound should reach the ear only after a lapse of at least 0.1 second after the original sound dies off. As the speed of sound is 340 m/s, the distance travelled by sound in 0.1 second is 34 m. This is twice the minimum distance between a source of sound and the reflector. So, if the obstacle is at a distance of 17 m at least, the reflected sound or the echo is heard after 0.1 second, distinctly.

Further, for reflection of any wave to take place, the size of the reflector should be large compared to the wavelength of the sound, which for ordinary sound is of the order of 1 metre. A large building, a mountain side, large rock formation etc. are good reflectors of sound for producing an echo. Also, for the reflected sound to be heard, it must have enough intensity or loudness. Moreover, if the echo is to be distinguished from the original sound the two should not mix or overlap. For this, the original sound should be of very short duration, like a clap or shout.

So, following conditions could be listed for formation of echo:

- The size of the obstacle/reflector must be large compared to the wavelength of the incident sound (for reflection of sound to take place).
- The distance between the source of sound and the reflector should be at least 17 m (so that the echo is heard distinctly after the original sound is over).
- The intensity or loudness of the sound should be sufficient for the reflected sound reaching the ear to be audible. The original sound should be of short duration.

Advantages and Disadvantages of Echoes

- Echoes can be useful or a nuisance. In a concert hall, echoes can ruin a performance if the walls and ceiling are not properly designed. If the walls are too hard, or too flat, they make good reflecting surfaces for the sound waves.
- Echoes can be used to give vital information. A sonar (Sonar stands for sound navigation ranging) device sends out high frequency sound waves from a ship to find out how close the vessel is to the sea bed. An ultrasound scanner, particularly known for giving images of the unborn baby, works in roughly the same way.
- Bats use echoes to navigate as they fly in the night. This works on the same principle as sonar and ultrasound scanner. The bat sends out tiny, high pitched squeaks, which bounce off the objects in the bat's flight path. The echoes reach the bat, which then adjusts its course to avoid the obstacles. Many bats have very large ears to catch as much of the reflected sound as possible.

- When animals such as bats and dolphins use echoes, it is called echo location. They use it to find their way around or to locate prey. Echo location describes the way of how some animals detect the size and position of objects around them.

- At night, bats use echolocation to guide them in flight. They send out tiny 'clicks', which bounce off objects and return to the bat. It builds up a 'sound' picture of its surroundings.

Reverberation

Due to reflection of light a sound created in a big hall will persist until it is reduced to a value where it is no longer audible.

This persistence of audible sound due to the successive reflections from the surrounding objects even after the source has stopped to produce that sound is called reverberation.

There should not be excessive reverberation. To reduce reverberation, the roof and walls of the auditorium are generally covered with sound- absorbent materials like compressed fibre -board, rough plaster or draperies.

Practical Applications of Reflection of Sound

Some applications of the principle of reflection of sound are:

- Megaphone
- Hearing Board
- Sound Boards

Megaphone: Megaphone is a horn-shaped tube. The sound waves are prevented from spreading out by successive reflections and are confined to the air in the tube.

Hearing aid: It is a device used by the people who are hard of hearing. Here the sound waves, which are received by the hearing aid are reflected into a narrower area leading to the ear.

Sound Boards: Curved surfaces can reflect sound waves. This reflection of sound waves is used in auditorium to spread the waves uniformly throughout the hall. Reflection of sound waves is done by using Sound Boards. The speaker is located at the focus of the sound board.

Musical Sound and Noise

A musical sound can be defined as a pleasant continuous and uniform sound produced by regular and periodic vibrations.

Example: The pleasant sound produced by a guitar, piano, tuning fork etc.

Noise can be defined as an irregular succession of disturbances, which are discordant and unpleasant to the ear.

Bats and dolphins can detect the presence of an obstacle by hearing the echo of the sound produced by them. This process is called sound ranging.

Range of Hearing

Sound waves are emitted from a vibrating source and transmitted through air. The human ear can hear sound waves in the range 20 Hz and 20 KHz. This range is known as audible range. The sound waves having frequencies above the audible range are known as ultrasonic waves and it is usually referred as ultrasound. The sound waves having frequencies less than the audible range are called infrasonic waves.

Applications of Ultrasound

- It is used for medical diagnosis and therapy and also as a surgical tool.
- Bats and porpoises use ultrasound for navigation and to locate food in darkness.
- It is used to detect defective foetus.
- It is used as a tool in the treatment of muscular pain.
- Ultra sonography (is a technique of 3-dimensional photographs with the help of ultrasonic waves) is used to locate the exact position of an eye tumour.
- Ultrasound is generally used to clean spiral tubes,electronic components etc.
- Ultrasound are used to detect cracks and flaws in metal blocks.

SONAR

One of the most important applications of the reflection of sound is oceanographic studies. For this purpose, we use a system called the SONAR. The SONAR is abbreviated form of Sound Navigation and Ranging. The SONAR system is used for detecting the presence of unseen under water object, such as submerged submarine, a sunken ship, iceberg and locating them. In Sonar ultrasonic waves are sent in all directions from the ship and are then received on their return after reflection.

Determination of the depth of an ocean

The depth of an ocean is determined with the help of SONAR.

Sonar uses ultrasonic waves to detect and locate objects under water.

Ultrasonic waves produced from the transmitter kept in a ship are directed towards the ocean floor.

The ocean floor reflects these waves.

By measuring the time interval t between the generation of the wave and reception of the echo, we calculate the depth of the ocean by using the relation

$S = \frac{v \times t}{2}$ Where v is the velocity of ultrasonic waves.

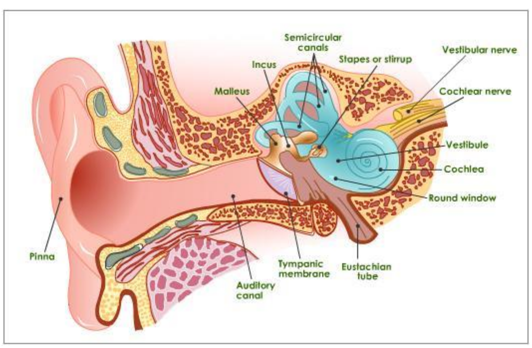
Echolocation

- Echolocation is a method of sensory perception by which certain animals orient themselves to their surroundings, detect obstacles, communicate with others and find food.
- Bats use echolocation to navigate in the dark and find food.
- A bat emits a series of short high-pitched ultrasonic waves from its mouth or nose.
- These sound waves travel away from the animal.
- Then they bounce off the objects in the animal's path creating an echo.
- A bat can determine the size and shape of the obstacle in their path, the direction of motion of the prey and also the direction of motion.
- This echolocation system is so accurate that bats can detect insects, the size of gnats and objects as fine as a human hair.
- Like bats, dolphins also emit high-frequency sound waves and are able to detect obstacles in their path.
- Thus dolphins can avoid fishing nets and also detect fish at night or even in muddy water through which it is not possible to see.

Structure of Human Ear

Ears are extremely sensitive device with the help of which we are able to hear.

The ear consists of three basic parts - the outer ear, the middle ear, and the inner ear. Each part of the ear has a specific role in the task of detecting and interpreting sound. The outer ear is called pinna. It collects and transmits the sound to the middle ear through the auditory canal.



At the end of the auditory canal there is a thin membrane called the eardrum or tympanic membrane. The eardrum moves inward and outward as the compression or rarefaction reaches it. In this way the eardrum vibrates. These vibrations are amplified by the three bones namely the hammer, anvil and stirrup in the middle ear.

The middle ear transmits these vibrations to the inner ear. Inside the inner ear, the vibrations or the pressure variations are converted into electrical signals by the cochlea. These electrical signals are sent to the brain via the auditory nerve and the brain interprets them as sound.